DESIGN OF
PEORIA - GALESBURG, ELECTRIC RAILWAY

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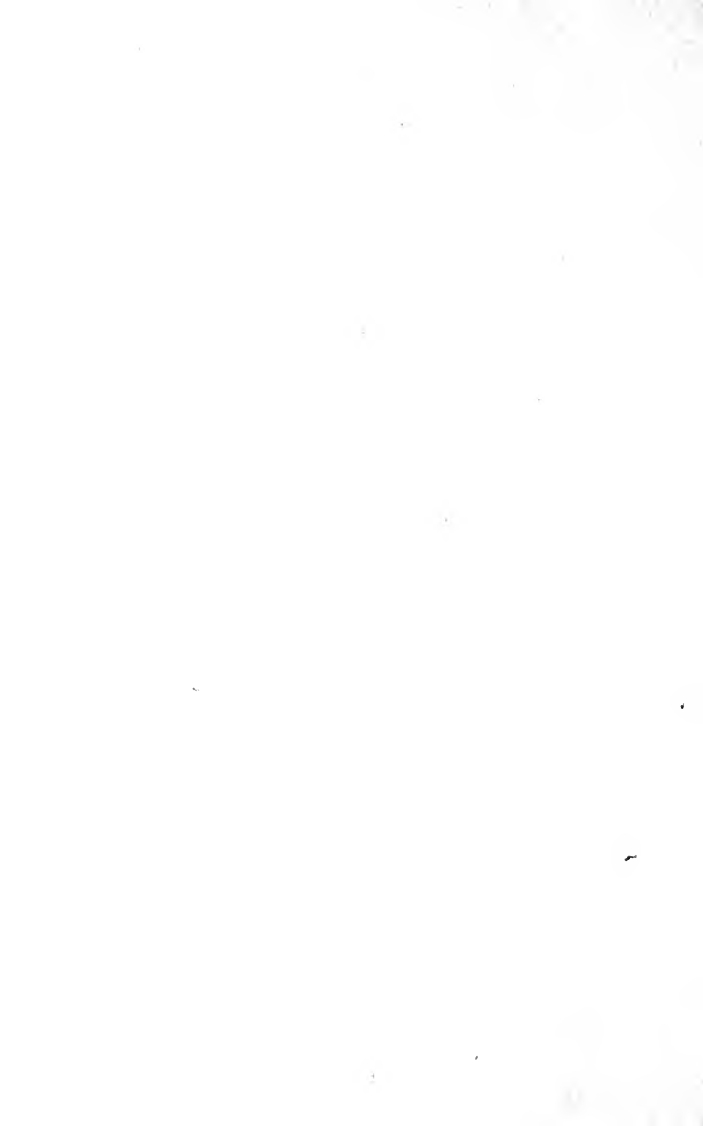
D E S I G N

OF THE

PEORIA - GALESBURG ELECTRIC RY.

A THESIS

PRESENTED BY

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and
E. Louis Hoffman

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Approved
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PREFACE

This thesis will consist of two parts.
Part A. dealing with the preliminaries,
constituting by themselves a statistical and
observational report which will show whether
the relations between probable revenue and
probable cost are such as will probably
produce a proper return upon the investment,
whether the enterprise is worth expending the
considerable amount of money which will be
required for the subsequent engineering
work.

Part B. will contain the final deter-
minations and specifications of the main
engineering features of the project.

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PART A

PRELIMINARIES

<u>PART A</u>

PRELIMINARIES.

1. <u>GENERAL</u>

This thesis will be based on alignment and grades shown by maps and profile, which we were permitted to use by the projectors of the Peoria, Canton and Galesburg Electric Railway. Recommendations for such type of road and equipment as will be found best suited will be made, -- together with preliminary estimates of probable cost and earning power.

This work will be put in the form of an engineer's report, but methods by which results were determined will be clearly indicated and discussed.

2. <u>PROJECT</u>

The project contemplates the construction of a high-speed interurban electric railway from Peoria in Peoria County, Illinois, via. Farmington County, to Galesburg, Knox County. The distance between Peoria and Galesburg is 50 miles. The project will traverse the following centers of population: Maxwell, Eden, Trivoli, Cramers, Farmington, Uniontown, Maquon, Gilson,

Knoxville and East Galesburg. The general
location of the project is shown on Sheet #1.

3. RIGHT OF WAY

The project will be located on a
private right of way, except in the cities of
Peoria and Galesburg where use of the street
railway-tracks will be made.

4. TERMINALS

1. PRIMARY TERMINAL

From a traffic standpoint the primary terminal of the project is Peoria. Its growth has been steady and rapid, as will be seen from the curve on Sheet #2 plotted from the U. S. Census statistics up to 1910. The population in 1914, according to the city directory of Peoria, is 89,500, -- approaching closely that which would be found by extending the curve.

Peoria, the second city of Illinois, is an important commercial and manufacturing center. It is situated on the Illinois River which will in time become a portion of the "Great Lakes to Gulf" waterway. It is the county seat of Peoria County.

Institutions of great commercial importance are: Keystone Steel and Wire Co., Jobst and Bethard, the Wilson Grocery Co. and Oakford and Fahnestock, wholesale grocers; The Kingman Plow Co., Clarke Bros., The Woolner Co. and the Corning Co., distillers, -- and a great number of other industries.

Furthermore, Peoria is known as a convention city, as will be seen from the fact that from June, (1913) to January, (1914) eight conventions had been held. Points of historic interest which also would help to produce traffic, are: the Site of the Lincoln - Douglas Debate; Indian Lookout Point; Site of Fort Clark and that of Fort Creve Coeur, the Landing Place of Marquette, Joliet and La Salle, -- and other points of just as much interest.

2. SECONDARY TERMINAL

Galesburg, the secondary terminal, is the county seat of Knox County. Its population according to the city directory is (in 1914) 25,000. Its growth, like that of the primary terminal, has been rapid, -- as will be seen from the curve on sheet #3. It is situated on the main lines of the Chicago, Burlington and Quincy and the Atchison Topeka and Santa Fe Railroads, and is one of the most important division -- points on the former, which has here large shops and freight classification yards; its tie-treating plant located here, is the largest in the country.

Among the important industries are: The Pur-
ington Paving Brick Works, claimed to be the
largest in the world; The Frost Mfg. Co., making
boilers, engines, etc.; The Johnson Refinery
Co.; The Wenzelman Mfg. Co., making agricul-
tural implements; the Jordan Co. and the Gales-
burg Grocery Co., big wholesale grocers; National
Biscuit Co., covering the territory comprising
Knox, Warren, Mercer and Henderson Counties;
Sinclair Bros., shipping great amounts of ice-
cream and soft drinks over a radius of 70 miles.

A notable characteristic of both
Peoria and Galesburg, is the fine character of
their public buildings, churches, schools,
railroad stations, etc.

5. TERMINAL FACILITIES

The route of the project in Peoria
is shown on Sheet #4. A new terminal is now
under construction for the Illinois Fraction
System, at Hamilton and Jefferson Sts.; rights
to use this terminal could be secured. The
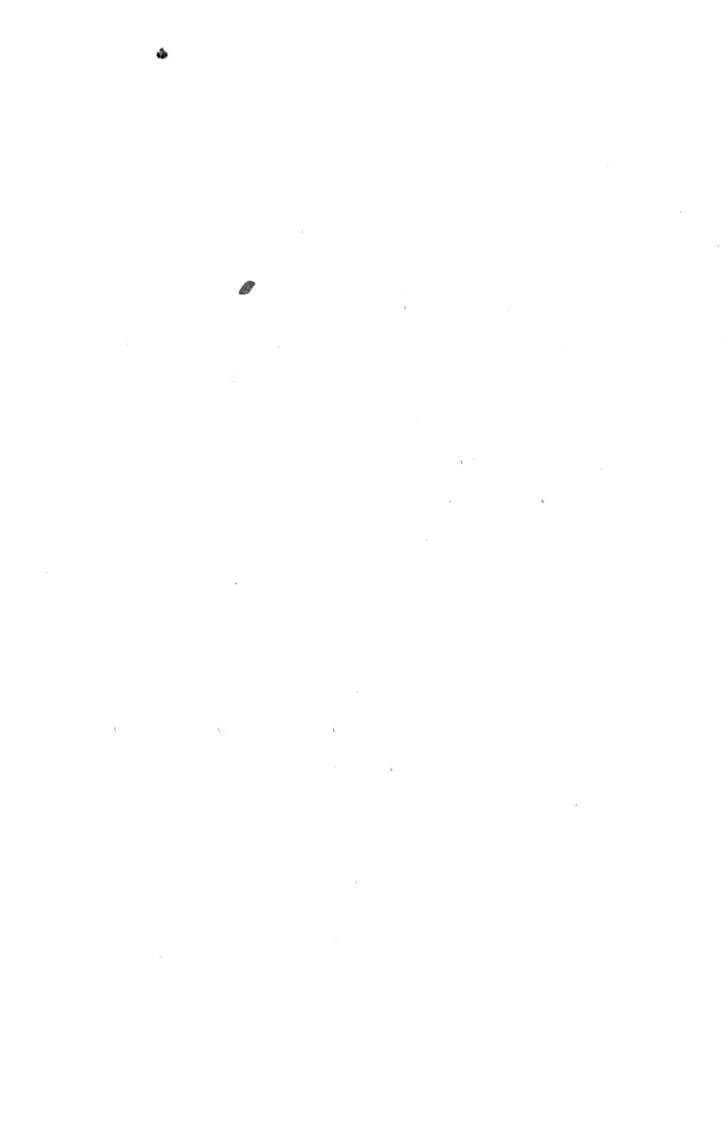
length of the line here is 3.17 miles.

Sheet #5 shows the route in Galesburg where the length of the line is 1.9 miles.

6. <u>POPULATION</u>

With the exception of the coal-mining industry, the territory traversed is a strictly agricultural one.

The predominant item in the revenue account of electric interurban railways is passenger revenue. In the present stage of development of such lines, with their limited operations in the express and freight fields, all the items composing revenue from transportation are of little consequence compared with passenger revenue. It follows logically that the character of the population served by such lines has a distinct hearing upon operating revenue. Therefore, an analysis of the population into its characteristic components is a quite necessary step in establishing the details of this relationship.

The population served by an electric interurban railway may be divided as follows:

primary terminal population, secondary terminal
population, and the intermediate or tributary
population. The density of the tributary popula-
tion in the case of the project was determined
by approximating its aggregate within one mile
on each side of the line, in spite of the fact
that this method is rather crude because many
local conditions may influence the extent of the
zone limiting the tributary population. There
is always a possibility in any such problem
that the assumption of uniform distribution
of the township population will prove to be
incorrect. Nevertheless, this method was
used since more accurate data could not be
obtained.

Determination of Tributary Population

PEORIA COUNTY

Total population (1910) ------------100,255

Land Area, sq. m. -----------------   636

Population per sq. m. --------------   157.6

Rural population per sq. m. --------   48.2

% Rural Population ------------------ 30.56

% Urban Population -----------------   69.44

Number of farms -------------------- 2717

Townships

	Population in 1910		Area (sq. m.)
Kickapoo ----------	1376	----	7.2227
Limestone ---------	6147	----	7.2227
(Maxwell)			
Logan -------------	1374	----	7.2227
(Eden - Hanna City)			
Trivoli ----------	924	----	7.3006
(Cramers - Trivoli)			

KNOX COUNTY

Total population (1910) ------------46,159

Land Area, sq. m. ------------------- 717

Population per sq. m. -------------- 64.9

Rural population per sq. m. ------- 33.9

% Rural population ----------------- 52.15

% Urban population ----------------- 47.85

Number of farms ------------------- 2,860.

Townships

	Population (1910)		Area (sq. m.)
Haw Creek ----------	826	----	9.766
(Gilson)			
Knox ---------------	3263	----	9.766
(Knoxville)			
Maquon -------------	1187	----	9.668
(Maquon)			

FULTON COUNTY

Total population (1910) -----------49,549

Land Area, sq. m. ---------------- 884

Population per sq. m. ------------ 56.1

Rural population per sq. m. ------ 44.2

% Rural population ------------- 78.91

% Urban population -------------- 21.09

Number of farms ------------------- 5200

Townships

	Population (1910)	Area (sq. m.)
Farmington ---------- (Farmington)	4723	6.094

The portion of the intermediate population
which may be considered as tributary to the
line, was taken as the population of a strip
of territory one mile in width on each side
of the project. To determine the population of
such a strip it was assumed that the townships
through which the road extends was evenly
populated. The tributary population was
then found from the proportion.

$$\frac{\text{Tributary population}}{\text{Township population}} = \frac{\text{Area of strip}}{\text{Area of township}}$$

The township population was obtained from the
census reports and estimated, and the required
areas were scaled from topographical maps.

TRIBUTARY POPULATION

		Per mile
Farmington township---	$\dfrac{4723 \times 2}{6.094}$	-- 1000 (assumed)
Haw Creek Township ---	$\dfrac{826 \times 2}{9.766}$	-- 169
Knox Township --------	$\dfrac{3263 \times 2}{9.766}$	-- 668
Maquon Township ------	$\dfrac{1187 \times 2}{9.668}$	-- 245
Limestone Township ---	$\dfrac{6147 \times 2}{7.223}$	-- 1700
Logan Township -------	$\dfrac{1374 \times 2}{7.223}$	-- 380
Trivoli Township -----	$\dfrac{924 \times 2}{7.4}$	-- 250
Peoria Township ------	(estimated)-	1700

LENGTH OF THE INTERURBAN PART OF THE LINE

	Miles
Peoria - Hanna City --------------------	8.43
Hanna City - Eden ----------------------	1.99
Eden - Trivoli -------------------------	2.74
Trivoli - Cramers ----------------------	3.22
Cramers - Farmington -------------------	2.65
Farmington - Uniontown -----------------	6.637
Uniontown - Maquon - Gilson -----------	9.85
Gilson - Knoxville ---------------------	5.3
Knoxville - E. Galesburg - Galesburg --	5.02
Total -----	45.84

The tributary population per mile mul-
tiplied by the length of the line through the
respective townships will give the total
tributary population.

```
Peoria - Hanna City ---- 8.43 x 1700 --- 14,331
Hanna City - Eden ------ 1.99 x 380   ---      756
Eden - Trivoli --------- 2.74 x  380 ---   1,045
Trivoli - Cramers ------ 3.22 x  250 ---     805
Cramers - Farmington --- 2.65 x  250 ---     663
Farmington - Uniontown - 6.637 x 1000 --  6,637
Uniontown - Gilson ----- 9.85 x 245 ----   2,413
Gilson - Knoxville ----- 5.3  x 169 ----     896
Knoxville - Galesburg -- 5.02 x 668 ----   3,353
                    Tributary population 30,899

                           per mile    674
```

The resulting tributary population of 647
per mile is a very favorable figure compared
with that of similar roads.

Mr. L. E. Fisher (Elec. Ry. Jour.
8/23/13) in determining the tributary popula-
tion excludes the tributary farming population
on the ground that in a normal territory the
value of the farming population from the view-
point of its traffic productiveness is reflected
in the size and character of the towns and vil-
lages. If such a territory has fertile lands
it will support a greater town population, and
if the roads are good in a farming community

the sphere of the commercial activities of the
town will be increased and a larger population
will result. The logic of this reasoning is
apparent. In the case of the project, however,
the elimination of the tributary farming popula-
tion is difficult to effect, since it was impos-
sible to obtain exact information relating to
the density of this farming population, -- the
U. S. Census statistics failing to furnish
such data. However, they do give the number
of farms in each of the countries traversed.
Assuming five possible users of the line per
family and knowing the area of the county in
square miles, we can determine the farming popula-
tion per sq. m., on the assumption, again, that
this farming population is uniformly distributed;
also the length of route in each county being
known, the tributary farming population in each
of the three counties is found. Deducting
this tributary farming population from the
tatal tributary population determined above,
will give the intermediate town and village
population.

PEORIA COUNTY

Number of farmers in county ----------- 2717

Number of possible users of line ------ 13585

Number of sq. m. in county ------------ 636

Farming population per sq. m. $\frac{13,585}{636}$ 21.4

Length of line in Protia Tp.---------- 8.43 m.

Farming population 8.43 x 21.4 x 2 ---- 360.8

Length of line in Logan Tp. ----------- 4.73 m.

Tributary population 4.73 x 21.4 x 2 --- 202.4

Length of line in Trivah Tp. ----------- 5.87 m.

Farming population 5.87 x 21.4 x 2 ---- 251.2

KNOX COUNTY

Number of farmers -------------------- 2,860

Possible users -------------------- 14,300

Number of sq. m. in county -------- 717

Farming population per sq. m. ------- 20

Length of line in Maquon Tp. -------- 9.85 m.

Farming population 9.85 x 20 x 2 ---- 394

Length of line in Haw Creek Tp. ------ 5.3 m.

Farming population 5.3 x 20 x 2 ----- 212

Length of line in Knox Tp. ---------- 5.02 m.

Farming population 5.02 x 20 x 2 ----- 200.8

FULTON COUNTY

Number of farmers ------------ 5,200

Possible users ------------- 26,000

Number of sq. m. in county   884

Farming population per sq. m.   29.4

Length of line in Farmington Tp.   6.637 m.

Farming population 6.637 x 29.4 x 2 ----- 390.3

        Total Farming population ---- 2,012

        With allowance for error ---- 2,100

Total Tributary Population ----------   30,899

Tributary Farming Population -------   2,100
        Intermediate town and village 28,800
                population
                  Per mile   628

      A portion of the population of Gales-
burg could be included in that of the tributary
population on account of the fact that Peoria
is on the main line of several large railroad
systems which do not touch Galesburg that Gales-
burg is on the main line of the Santa Fe which
does not reach Peoria, and that the secondary
terminal is on the main line of the C. B. & Q.
which gives over a branch line a poor and very
infrequent service between these terminals.
Considerable interchange of passenger traffic

between the different railway systems is to be
expected and under these conditions more traffic
will originate in the primary terminal than is
usually the case.

7. FEEDER LINES

(1) Peoria

The steam roads touching Peoria are:
Chicago & Northwestern; C. & A.; C. R. I. & P.;
Lake Erie & Western; Peoria & Pekin Union; Toledo,
Peoria & Western; Chicago, Peoria & St. Louis;
Minneapolis & St. Louis; Big Four; C. B. & Q.
Electric roads having their terminals in Peoria
are: Illinois Traction System (connecting with
Bloomington, Champaign, Danville, Decatur, Spring-
field and St. Louis), and the Peoria Railway
Terminal (connecting with Bartonville, Hollis
and Pekin).

(2) Galesburg

The Santa Fe and the C. B. & Q. Railroads
will be the steam railway feeders. Electric feeder
lines will be the Peoples Traction Co., operating
an interurban line between Galesburg and Abingdon,
and the Rock Island Southern R. R., connecting
with Monmouth, Rock Island, Moline and Davenport.

(3) Farmington

Two steam roads will feed into the
project, -- the C. B. & Q. and the Minneapolis
& St. Louis. Branch lines from Lewistown,
Canton and Fairview will feed at Farmington.

8. COMPETITION

The only steam competition to the
project is that offered by the C. B. & Q. The
road operates three trains daily each way
requiring from 1 hour, 33 minutes to 1 hour,
55 minutes for the trip. The following is
a schedule of trains showing time of arrival
and departure at terminals, and time of trips:

LEAVE GALESBURG	ARRIVE PEORIA	TIME OF TRIP	
		Hr.	Min.
A. M. 4:40 --------- A. M. 6:25		1	50
10:20 ------ P. M. 12:10		1	50
P. M. 4:55 ------ 6:45		1	45

LEAVE PEORIA	ARRIVE GALESBURG	TIME OF TRIP	
		Hr.	Min.
A. M. 7:05 ------ A. M. 8:55		1	50
P. M. 3:00 ------ P. M. 4:55		1	55
7:10 ------ 8:43		1	33

The distance between city-limits of
Galesburg and Peoria is 45.34 miles. The project

could readily equal the average time of the
C. B. & Q. Considering the comparative fre-
quency of service by the interurban and the
steam road, and also the fact that the ter-
minals of the project are much nearer the busi-
ness centers of the cities, the effect of the
steam competition should be relatively small.

There is no electric competition
to the project.

9. OPERATION

For the greater part of the day an
approximately hourly schedule is assumed for
passenger service. The car selected will
contain a baggage compartment which will
enable the handling of package freight and
other small freight, such as dairy products,
eggs, etc.

10. CONSTRUCTIVE FEATURES

(1) ALIGNMENT AND GRADES.

Conditions of
alignment and grades are favorable through-
out. In Galesburg there are 2 curves and a
loop, making additional 4 curves. In Peoria,
there are 4 curves.

On the interurban portion of the
line the maximum curvature is 30 deg., or 1910 ft.
radius. The maximum grade is 2% including city
trackage. Of the interurban portion, 18.4% will
be targent and of this 6.8% will be targent over
trestles.

(2) GRADING

The profile shows a few grades
greater than 2%; these will cut or filled to
make 2% grades.

(3) RAILROAD CROSSINGS

According to the pro-
file there will be three crossings of steam roads,
viz., over the C. B. & Q. spur about 1.2 miles
from Galesburg; the C. B. & Q. main line about
3 miles from Galesburg and the C. B. & Q. and
Iowa Central at Farmington.

(4) BRIDGES

One steel bridge, 300 ft. long
will be erected across Spoon River, and one,
500 ft. long, across Kikapoo Creek.

(5) TRACK

For main track construction, 70lb.
A. S. C. E. standard "T" rails are assumed laid
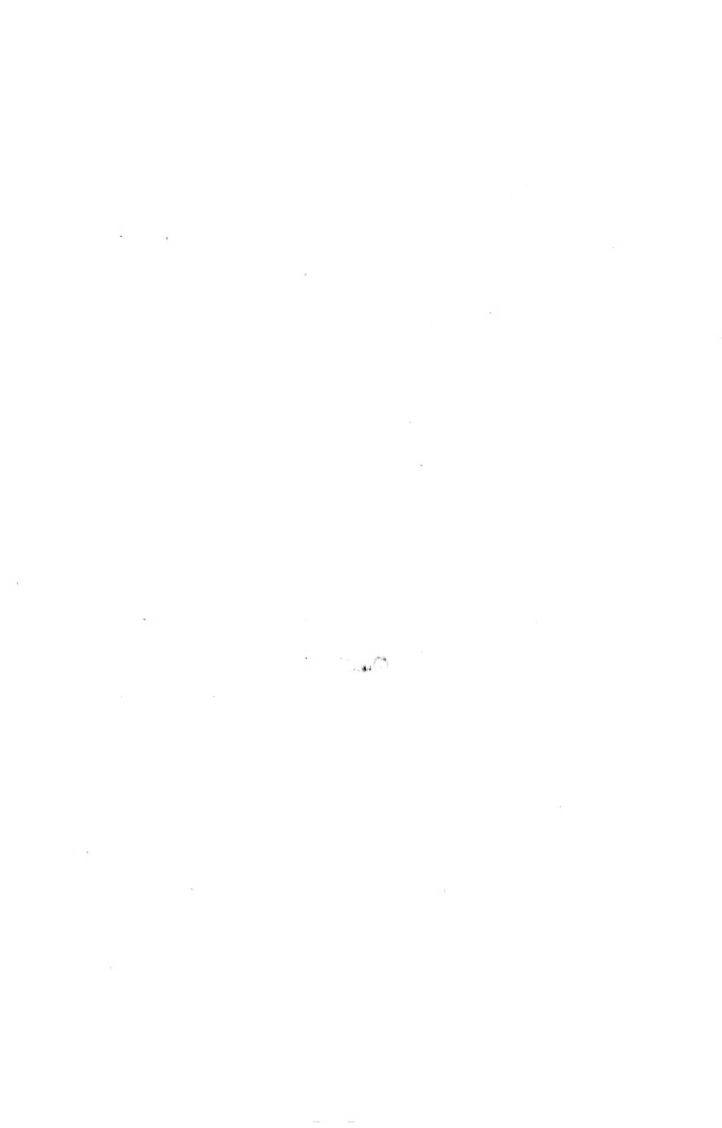
on ties spaced 2640 per mile.

(a) BALLAST

Ballast is just as essential
to the riding qualities of good track as good
rails and ties. Poor riding track which is
so due to poor ballast conditions introduces
stresses into a car body which eventually will
loosen nearly every joint of the structure.
Hence, besides regular ballast, a cushion for the
latter is contemplated. It will consist of 1 ft.
of gravel; this, with an additional 1 ft. of
broken stone will give excellent track.

(6) OVERHEAD LINE

The transmission voltage
will be, probably, 33,000; direct current
distribution is contemplated.

(7) POWER HOUSE AND SUBSTATIONS

Should the
erection of a power plant be found advisable or
necessary it will be located at Spoon River.
This point should be selected on account of the
nearness of the desirable water supply for the
feed water and condensing apparatus, and the
convenience and saving attained by depositing

the fuel in the bunkers directly from the coal barges. Only one independent substation will then be required, the power house acting as another substation. The extra substation would probably be located between Trivoli and Eden.

(8) ROLLING STOCK

Motor passenger cars are assumed, with smoking and baggage compartments, and equipped with 4-600-volt. motors and with multiple control. The car with equipment and passengers (the latter at 140 lb.) will weigh 45 tons.

(9) BUILDINGS:

A building will either be purchased or erected in Galesburg to be used as a terminal. In addition, a number of smaller stations and platforms will be needed along the line. An inspection shed, and a painting and repair shop will further be built. The repair shop will be adequate for all minor repairs. It is assumed that flange-turning and heavy repair work will be let out, as there are extensive railway shops in Galesburg.

11. PRELIMINARY DETERMINATION OF SCHEDULES AND EQUIPMENT

1. SCHEDULE

As stated before the project is to give approximately hourly service.

Reconnoissance showed no accurate data as to the distribution of the numbers of passengers to be carried. However, it was seen from the traffic on the C. B. & Q. between terminals, that the bulk of the business is done during the few hours of the morning and the evening, -- as would be expected.

The schedule is plotted with time of day in hours and minutes as ordinates and distances in miles as abscissae. After the scales of coordinates have been determined, a series of slanting lines are drawn to represent the progress of the car from station to station. This chart is sufficiently accurate for a preliminary study of traffic possibilities, power requirements, etc. It is shown on Sheet #7. The time assumed was 1 hour 45 minutes, cars running hourly

from 5 A. M. to 7 A. M, from 5 P. M. to
8 P. M. and at 2 hour intervals from 7 A. M.
to 5 P. M. the last car leaving either ter-
minal at 11 P. M. It will be seen from the
chart that 7 cars could in an extremity
perform the service. However, an additional
3 cars were assumed, making a total of ten.

PEORIA TO GALESBURG		GALESBURG TO PEORIA	
A. M. (1)	5:00 --- 6:45	(1)	5:00 --- 6:45
(2)	6:00 --- 7:45	(4)	6:00 --- 7:45
(3)	7:00 ---8:45	(7)	7:00 --- 8:45
(4)	9:00 ---10:45	(1)	9:00 ---10:45
(5)	11:00 ---12:45	(2)	11:00 ---12:45
P. M. (1)	1:00 --- 2:45	(3)	1:00 --- 2:45
(2)	3:00 --- 4:45	(4)	3:00---- 4:45
(3)	5:00 --- 6:45	(1)	5:00 --- 6:45
(4)	6:00 ---- 7:45	(2)	6:00 --- 7:45
(6)	7:00 --- 8:45	(5)	7:00 --- 8:45
(7)	8:00 --- 9:45	(3)	8:00 --- 9:45
(1)	11:00 --12:45	(6)	11:00 ---12:45

```
          Car #1 remains in Galesburg
           "  #2     "    " Peoria
           "  #3     "    "   "
           "  #4     "    " Galesburg
           "  #5     "    " Peoria
           "  #6     "    "   "
           "  #7     "    " Galesburg
```

As a second step, the line was assumed to be straight and level and the stations or steps at equal distances apart. In this way the length of the average run was found to be 19,500 ft.

WEIGHT TO BE ACCELERATED

Weight of car body, equipment, etc. 80,000#

Seating capacity 62

Weight of average passenger load
$$\begin{array}{r} 62 \times 140 = \underline{8,680\#} \\ \text{Total weight} \quad 88,680\# \end{array}$$

Assume it to be 45 tons.

TRAIN RESISTANCE

Let W = Weight of car,

V. speed in miles per hour (assumed schedule)

a. Cross-sectional area of front of car in sq. ft.

Then the following empirical formula gives the total train resistance in pounds per ton weight of car,-

$$F = \frac{90}{\sqrt{W}} + .03V + \frac{.002V^2}{W}\cdot a$$

With speed taken at 41 m.p.h., and area equal to (9 x 11½)= 104 sq. ft. from dimensions shown by drawing (of car selected) on Sheet #8, the total train resistance was found to be 16.2 pounds per ton.

From the curves for a single car by
A. H. Armstrong, by interpolating for a 45-ton
car, the value of the train resistance was
found to be 18.25 pounds per ton. Taking a
mean of these two the total train resistance
per ton is 17.2 pounds. Sheet #9 shows the
curve of train resistance for a 45-ton car.

PRELIMINARY SPEED-TIME CURVE

By the use of the method given by
C. T. Hutchinson the best acceleration rate
was found to be 1.5 miles per hour per second,
with a duration of stop of 30 seconds. The
braking rate was taken as 1.5 m. per hr. per
sec. With the above rate of acceleration the
energy input was found to be 61 watt-hours per
ton mile, and the motor capacity 9.8 hp. per
ton weight.

Motor G. E. - 66 - A. - 9 of 125
hp. at 208 amperes and 500 volts was taken
to be best suited. Several gear ratios were
tried out, and the ratio of pinion 29 to gear
60 (= 2.07) was decided on for trial on the
speed-time curve.

If W = total mass accelerated in tons,

a = acceleration in m.p. h. p. s.,

w = weight in tons plus 10% for rational inertia,

t = Tractine effort in pounds due to train resistance,

then $T = (91.1 \ a \ W) + t \ W = 7799$ lb. or 1950 lb. per motor.

From the curves showing the operating characteristics of this motor, shown on Sheet #10, a tractine effort of 1950 lb. will be exerted at 25.5 miles per hour when a current of 223 amperes will be taken.

The various acceleration rates for the speed-time curve were calculated both by the formula $a = \dfrac{T - tW}{100 \ W}$ and by the "differential" method using the expression $a = \dfrac{dv}{dt}$

From the preliminary speed-time curve shown on Sheet #11 it is seen that the average run of 19,500 ft. can be made in 306 seconds; the accelerating, coasting, and braking periods are respectively, 166 sec., 121 sec., and 19 sec. The maximum speed reached is 51 miles per hour.

2. EQUIPMENT

CURRENT CURVE

The current curve on Sheet #11 was plotted in terms of amperes per car. The periods when the motors are in series and in parallel are shown.

VOLTAGE CURVE

The voltage curve was next plotted, starting at the voltage which is required to overcome the ohmic resistance of the motor with 217 amperes flowing; using 0.35 ohm as the resistance gave an RI drop of 76 volts for the initial voltage value. As the resistance is cut out, the voltage rises till it reaches 600 volts, where it remains until the power is cut off.

ROOT SQUARE CURRENT CURVE

The current which, when flowing continuously, will give the same average loss, will be the square root of the average of the squares; i. e., the equivalent heating current is the square root of the mean square current. Dividing the sum of these squares by the total number of seconds in the cycle (306 + 30), and

extracting the square root of the quotient,
there results the equivalent heating current
of 72 amperes. The average voltage was found
to be 308 volts. These results were compared w
with those given for the #89 Westinghouse Motor,
which has a maximum capacity of 105 hp. at 400
volts. The motor under consideration is volted
at 125 hp. and takes approximately the same
current as the above Westinghouse motor. It
will, therefore, be fair to conclude that this
trial motor will not be over heated.

The results thus found could not be
checked by determining the losses since no loss
data for this motor could be obtained either by
reference to technical literature or by applica-
tion to the manufacturers (General Electric Co.).

12. <u>PROBABLE OPERATING REVENUE</u>

The project under consideration will
be a normal railway. The general characteristics
of such a railway are: (a) private right-of-way
outside of cities and villages; (b) entrance into
cities and towns over streets secured by fran-
chises; (c) ample and modern car equipment; (d)
roadbed with reasonable grades and curves;

(e) substantially hourly service, with schedule
practically equal to that of the competing steam-
railway lines; (f) handling of package freight,
and (g) a rate of fare approximately 2 cents per
mile.

As stated above, the chief item in the
revenue account of an electric railway is that
of passenger revenue. Hence, other items which
could be considered in the case of the project,
such as, baggage revenue, mail revenue, express
revenue and milk revenue, also revenue from
advertising and the sale of power, will not be
taken up in the preliminary determination of
probable revenue.

Extensive statistics support the conclu-
sion that approximately the operating revenue
varies directly with the aggregate of the interme-
diate town and village population. Referring to
the curves drawn by Mr. Fischer, and representing
the relation between the earnings of 36 interurban
roads and the town and village population, it is
seen that the average is shown by a line in-
dicating $10. per capital of intermediate town
and village population. See Sheet # 6.
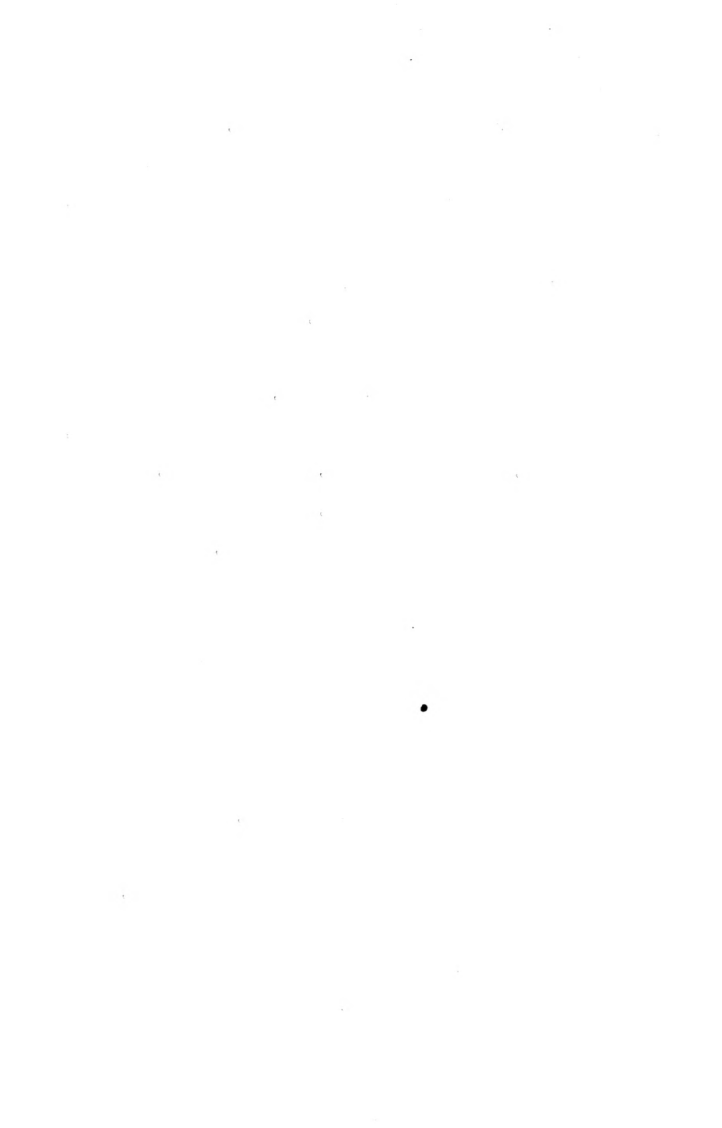
By earnings here is meant the operating revenue from intercommunication of primary terminal and intermediate population and from the inter-communication of intermediate population centers only.

Because both the primary and secondary terminals are important manufacturing centers, and the former also an important railroad center, there will be tne average cause for intercommunica-tion.

From Mr. Fischer's statistics it is seen that where tne distance between terminals is 40 miles or less, the revenue from the intercommunica-tion of (1) the population of tne secondary terminal and the intermediate population and (2) the popula-tion of tne primary terminal and that of the seconnary terminal, -- will be a minimum of $6. per capita of that secondary terminal population; also that when the distance between terminals is greater than 40 miles, this revenue will be diminished practi-cally 1% for each mile increase. In the present case, the distance between terminals is 46.58 miles. Hence, the reduction in tne secondary revenue will be 6.58%, i. e. a reduction of $.40 per capita, which gives $5.60 per capita.

As determined in Section 6, the
intermediate town and village population is
28,800.

Primary Operating Revenue

28,800 Intermediate population at $10. per

capita, $288,000

Secondary Operating Revenue

23,000 Secondary terminal population at $5.60

per capita $128,800
Total Gross Reven.$416,800
per mile   8,015.

13. PROBABLE OPERATING EXPENSE

1. Way and Structures
Approximately $832. per mile-track/

year---- $832.

2. Equipment and Depreciation
Approximately $500 per mile-track/

year---- $500.

3. Traffic
Approximately $100 per mile/ year-- 100.

4. Conducting Transportation
Approximately $1600. per mile/

year ---- 1600.

5. General and Miscellaneous
Approximately $650 per mile/

year ---- 650.
Total Operating Expenses/
mile ----$3682.

Taxes - per mile ---------- 318.

The first account, way and structures, takes in the following details: superintendence of way and structures, maintenance of roadway and maintenance of track.

The second or the equipment account includes: superintendence of equipment, maintenance of power-plant and substation equipment; maintenance of cars; maintenance of electric equipment of cars; equipment expenses connected with shop machinery and tools; and the depreciation of equipment.

The traffic account includes advertising and superintendence.

The account under the heading "conducting transportation," includes: superintendence of transportation; all costs connected with the generation of power and the operation of cars.

The fifth account includes: salaries and expenses of the general office force; legal expenses; insurance; rent of tracks and terminal.

Taxes vary on different roads in differnet states. In Illinois, the average of various roads reaches $318. per mile of track.

The statistics compiled by Mr. L. E. Fischer were used in this approximation of operating costs.

14. ESTIMATED COST

The following is an estimate of the cost of construction and equipment based on data complied by Prof. Nichols (A. I. T.) and on Gillette's "Cost Data."

1. ROAD-BED

Per mile of route. Single Track.

(a) Material.

```
Track -----110 tons, 70#, "T" rail $30.----3300
Ties ------2640 -------------------- 0.50 1320
Spikers, Bolts, Nuts, Plates, Bonds, etc.  800
2000 cu. yd. Ballast -------------- 0.80 1600
Bridges, abutments, culverts ------      1000
                 Total Material------------ $8120
```

(b) LABOR

```
Excavation and embankments -----------   $1,500.
Bridges, abutments, culverts ---------       500
Laying of Track ----------------------       700
Bonding, etc.-------------------------       300
Teaming material ---------------------       250
                  Total Labor -------      3,250
              Total material and Labor --- 11,370
          Engineering and Superintendence 10 % 1,137
                         Total -------    12,507
                 For double track -----   $25,014
```

2 OVERHEAD LINE

Trolley with Bracket Construction, 130 ft. span.

(a) Material

	$	$
88 - 35 ft. wooden poles ------	5.50	484.00
44 - 2 pin arms ---------------	0.45	19.80
88 - Arm Braces, etc. --------	0.60	52.80
88 - Feeder Insulators and pins	.45	39.60
88 - Strain Insulators & pins ---	.50	44.00
2500 ft., 1/4" Steel wire, 288#	.08	23.04
88 - Trolley Suspensions -------	.80	70.40
88 - Trolley ears ------------	0.20	17.60
8 - Strain ears ------------	0.60	4.80
8 - Feeder ears ------------	0.50	4.00
4 - Splicing Sleeves --------	1.75	7.00
2 Lightning arresters -------	12.50	25.
20 Anchor rods -------------	1.80	36.
10,800 ft. 4/0 Trolley, 6,800#	0.80	1700.
3,000 ft. 5/16" Steel strand		
Cable 630 #	0.80	50.40
88 Eye-bolts nuts for cable		
spans	0.20	17.60

Total Material -----$2596.04

(b) LABOR

Distribution and erection of 88 poles $5.00 $440.

Stringing of trolley ---------------------- 60.

Incidentals --------------------------------- 60.

Total Labor ------ $560.

Total Material and Labor   3,156.04

Engineering and Superintendence 10% ------ 315.60

Total -----$3,471.64

-33-

Additional to (2) for

3 - Phase Transmission Line on Same Poles.

44 - 40 ft. Poles, additional price $2.00		$88.00
44 - 4 Pin Cross-arms ------------ 1.10		48.40
88 - Cross-arm braces ------------- 0.70		61.60
140 - 33,000 volt Insulators ------ 0.70		98.00
140 - 33,000 " Insulator pins -- 0.50		70.00
16,500 ft., #2 Copper wire 6650# -- 0.25		1,662.50
5400 ft., 1/4" Steel ground cable, 621# 0.08		49.68
500 ft. #8 B. & S. Copper wire for ground connections 25# 0.25		6.25
Stringing high-tension conductor and ground wire --------		120.00
Total -------------		$2,204.43
Engineering and Superintendence 10% ----		220.44
Total -----------		$2,424.87

POWER STATION

Building ------------   20,000

Equipment $\begin{Bmatrix} \text{steam} \\ \text{electric} \end{Bmatrix}$ -- $\dfrac{100,000.}{120,000.}$

Engineering and Supertendence
                    10% ---- 12,000.
                    Total --- $132,000.

Per mile ---------$2,538.50

SUBSTATIONS

    3 Buildings ------------6,000.

    7 Syn. Converters ---- 20,000.

    Step-down Transformers 12,000.

    3 Switchboards ------ 6,000.

    Wiring ------------- 3,000.
               Total 47,000

Eng'g and Superintendence
          10% -- 4,700.
          Total 51,700

      Per mile ------------- $994.23

WAITING-ROOMS, PLATFORMS, ETC:

    Terminal Building in Galesburg $35,000.

    Waiting-rooms, platforms, etc. 10,000
                               $45,000.

Eng'g and Superintendence 10%   4,500.
          Total -------- $49,500.

         Per mile ---- $952.

    Inspection Sheds and shops   15,000.

Eng'g and Superintendence 10%   1,500.
              Total $16,500.

        Per mile $311.

ROLLING STOCK

    10 motor passenger cars, 100,000
    Snow-plow, Construction
              car, etc. 27,000
                  $127,000.

Eng'g and Superintendence 3%   3,810.
          Total $130,810.

        Per mile ---------- $2,515.20

ESTIMATED COST PER MILE

1. Roadbed ----------------- $25,014.00

2. Overhead Line   (3,471.64) 5,896.51
   Transmission Line(2,424.87)

3. Power Station ----------   2,538.50

4. Substations ------------   994.23

5. Waiting-rooms, platforms, etc 952.00

6. Inspection-shed, shop ----   311.00

7. Rolling stock ------------ 2,515.20
                  Per mile $38,221.44

Total, for 52 miles --------$1,987,514.81

Interest, 6% ---------------   119,250.89

TOTAL ESTIMATED COST------- $2,106,765.70

          The estimated cost was calculated

on the 52 mile basis, to cover possible costs

of sidings, turnouts, etc.

15. SUMMARY

Total Gross Revenue ---------------- $416,800.

Total Operating Expenses 52 Miles at
                 $36.82 / mile 191,464.
          NET EARNINGS --------- $225,336.

Taxes, 52 miles at $318 / mile   16,536.

Net Earnings Applicable to Fixed
Charges and Surplus ------------- $208.800.

Interest on Construction Cost
     ($2,106,765.70 at 6%)   ------ 126,406.
Surplus Earnings Applicable to
                 Dividends ---- $ 82,394.

Assuming Preferred Stock $1,000,000.
                 Dividends, 6%   60,000.

                 SURPLUS ------$ 22,394.

16. CONCLUSIONS

The summary in the preceding section shows that the project is one of the best. All the determinations outlined above were made with somewhat exaggerated costs and a liberal allowance for error etc. against the project. The probable operating revenue of $8,015 per mile by far exceeds that of most roads similar to the project. The estimated cost of operation and taxes per mile, viz., $4,000. leaves a good balance.

Additional income will be derived from advertising and the probable future transfer of mail. Milk revenue and the income from other small freight handling will further increase the profits. Briefly, it can be said that without doubt, the project, with good and efficient management, should be one of the best-paying enterprises in the electric railway field.

-B-

FINAL DETERMINATIONS

1. Individual Runs Between Termini

To construct the individual speed-time curves, the grades and curvature were

taken from the profile and the alignment maps
respectively.

CORRECTION FOR GRADES AND CURVES

1. Grades

Since in railway work the angles of
grade are small, the sines are approximately
equal to the tangents, and therefore grades
may be expressed as the ratio of the vertical
rise to the horizontal length of grade. The
tractine effort necessary to move each ton
of car weight up a one percent grade is there-
fore $\frac{1}{100}$ x 2000, or 20 pounds; to draw the car of
45 tons up a grade of q per cent with uniform
speed requires

$$G = 20 \times 45 \times q \text{ pounds}$$

tractive effort. For a down grade G is consid-
ered negative.

2. CURVES.

Curvature of track presents additional
resistance to the motion of a car because of
increased flange friction. To neutralize this
effect a larger tractive effort must be exerted.
Curve resistence was taken as 0.6 pound per ton
of train weight per degree of curvature, -- this
being an average value.

At curves, the inner rail will not be

raised; hence, the brakes will be applied to
bring the car to the safe speed before reaching
the curve.

3.   Tables

                      OF

        GRADES, CURVES, AND CORRECTIONS

PEORIA LIMITS - MAXWELL   MAXWELL- PEORIA
                                                   LIM.
LENGTH FEET	CURVATURE DEGREES	% GRADE UP	DOWN	CORREC- TION. 1ᵇ/ton	CORRECTION 2ᵇ/ton
1400		LEVEL		0	0
200	3	DO.		1.8	1.8
35		DO.		0	0
315			0.35	-7	7
200	3		0.35	-5.2	8.8
1925			0.35	-7	7
200	2		0.35	-5.8	8.2
360			0.35	-7	7
1,990		1		20	-20
200	3	1		21.8	-18.2
80		1		20	-20
4,330		2		40	-40
1,315		0.32		6.4	- 6.4
200	3	0.32		8.2	- 4.6
1,585		0.32		6.4	- 6.4
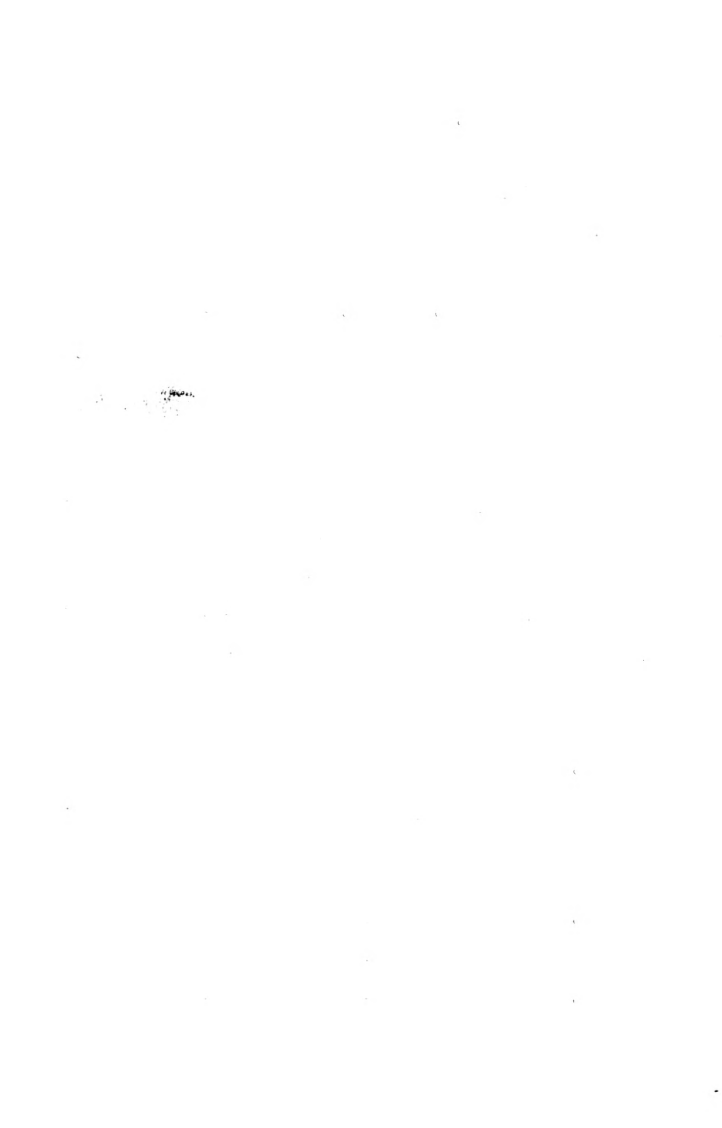
PEORIA LIMITS - MAXWELL

MAXWELL- PEORIA LIM.

LENGTH FEET	CURVATURE DEGREES	% GRADE UP	DOWN	CORREC- TION lb/ton	CORRECTION lb/ton
140		1		.20.	-20.
200	1	1		20.6	-19.4
1,610		1		20	-20
910		2		40	-40
1,120		Level		0	0
390			1.8	-36.	36
3,030		0.63		12.6	-12.6
20,735					

MAXWELL - HANNA CITY

HANNA CITY - MAXWELL

LENGTH	CURVATURE	% GRADE UP	DOWN	CORREC- TION	CORRECTION
420		0.63		12.6	-12.6
490		0.82		16.4	-16.4
415		0.17		3.4	- 3.4
175	0.5	0.17		3.7	- 3.1
2,450	0.5	0.69		14.1	-13.5
350		0.69		13.8	-13.8
1,000		1.60		32	-32
1,000		0.2		4	- 4
1,000		LEVEL		0	0
2,000			0.6	-12	12

MAXWELL - HANNA CITY				HANNA CITY - MAXWELL
LENGTH	CURVATURE	% GRADE UP DOWN	CORREC- TION	CORRECTION
875		0.75	15	-15
600	1.5	0.75	15.9	-14.1
3,025		0.75	15	-15
1,750		0.45	-9	9
875	1.5	0.45	-8.1	9.9
375		0.5	-10.	10
1,500		0.13	2.6	-2.6
2,500		0.4	-8	8
1,000		0.9	18	-18
1,900		0.37	7.4	-7.4
200	1	0.37	8	-6.8
425		0.37	7.4	-7.4
200	1	0.37	8	-6.8
275		0.37	7.4	-7.4
375		0.29	5.8	-5.8

25,175

EDEN - TRIVOLI				TRIVOLI - EDEN
LENGTH	CURVATURE	% GRADE UP DOWN	CORREC TION	CORRECTION
L 1,825		LEVEL	0	0
2,000		0.3	-6	6
1,800		0.39	-7.8	7.8

EDEN - TRIVOLI   TRIVOLI -
                                                    EDEN

LENGTH	CURVATURE	% GRADE UP	DOWN	CORREC-TION	CORRECTION
1,200		0.17		3.4	-3.4
2,000		0.55		11	-11
1,600			0.31	-6.2	6.2
1,400		0.71		14.2	-14.2
2,075		0.13		2.6	-2.6
200	2	0.13		3.8	-1.4
125		0.13		2.6	-2.6
175		0.63		12.6	-12.6
200	2.	0.63		13.8	-11.4
900		0.63		12.6	-12.6
15,500					

HANNA CITY - EDEN   EDEN -
                                                HANNA CITY

LENGTH	CURVATURE	% GRADE UP	DOWN	CORRECTION	CORRECTION
1,200		0.29		5.8	-5.8
200	1	0.29		6.4	-5.2
625		0.29		5.8	-5.8
200	1	0.29		6.4	-5.2
4,400		0.29		5.8	-5.8
1,700			0.88	-17.6	17.6
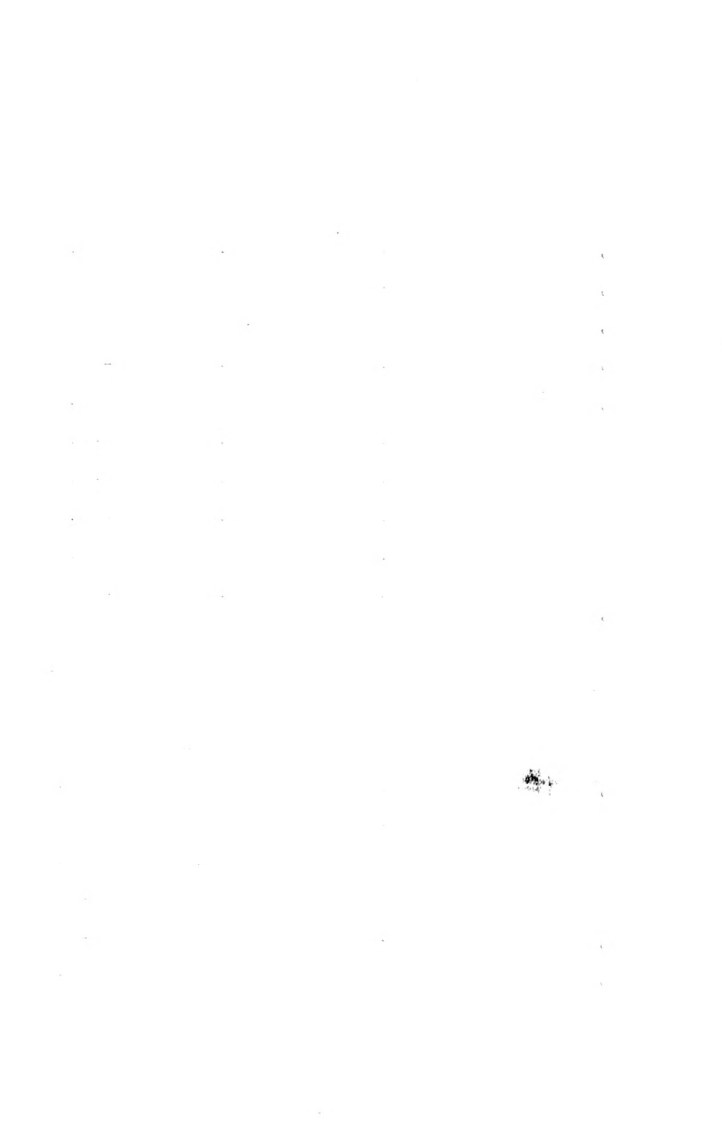
HANNA CITY - EDEN				EDEN - HANNA CITY
LENGTH	CURVATURE	% GRADE UP DOWN	CORREC- TION	CORRECTION
300		LEVEL	0	0
2,000		0.4	8.	-8.
175 10,800		LEVEL	0	0

TRIVOLI - CRAMERS				CRAMERS - TRIVOLI
LENGTH	CURVATURE	% GRADE UP DOWN	CORREC- TION	CORRECTION
325	1	0.63	13.2	-12
950		LEVEL	0	0
200	1	DO	0.6	0.6
1,350		DO	0	0
1,200		0.67	13.4	-13.4
1,800		0.43	-8.6	8.6
2,000		0.1	2	-2
1,000		0.5	10	-10
1,000		0.1	2	-2
1,600		LEVEL	0	0
2,400		0.42	8.4	-8.4
1,925 15,750		0.3	-6.	6

		CRAMERS – BARMINGTON			FARMINGTON – · CRAMERS
LENGTH	CURVATURE	% GRADE UP DOWN		CORREC- TION	CORRECTION
1,475			0.3	-6	6
1,600		LEVEL		0	0
1,600		0.7		14	-14
1,000			0.3	-6	6
5,000		LEVEL		0	0
1,200			0.21	-4.2	4.2
200	1		0.21	-3.6	4.8
1,000			0.21	-4.2	4.2
1,525			0.38	-7.6	7.6
425	5.7	LEVEL		3.42	3.42
1,175		DO		∅	0
175	11.5	DO		6.9	6.9
1,180			0.94	-18.8	18.8
1,050			0.1	-2	2
360			0.28	-5.6	5.6
680			0.44	-8.8	8.8
330			091	-18.2	18.2
250		LEVEL		0	0
400			0.75	-15.	15.

20,625

FARMINGTON - UNIONTOWN				UNIONTOWN - FARMINGTON
LENGTH	CURVATURE	% GRADE UP DOWN	CORREC- TION	CORRECTION
450		0.81	16.2	-16.2
C. B. and Q. IOWA CENTRAL				
1,175		0.81	16.2	-16.2
575	10.4	0.81	22.44	- 9.96
270		0.81	16.2	-16.2
1,000		0.2	-4.	4
580		0.54	10.8	-10.8
200	1	0.54	11.4	-10.2
520		0.54	10.8	-10.8
700		0.71	-14.2	14.2
1,100		1.8	-36	36
600		1	-20	20
1,900		LEVEL	0	0
2,400		2 0.58	-11.6	11.6
1,300		2	-40.	40.
700		LEVEL	0	0
900		2	40	-40
600		1.1	22	-22
1,705		0.52	10.4	-10.4
200	2	0.52	11.6	9.2
595		0.52	10.4	-10.4
1,900		1.6	32	-32
2,000		1.5	-30	30
2,700		0.76	-15.2	15.2

FARMINGTON - UNIONTOWN   UNIONTOWN -
                                             FARLINGTON

LENGTH	CURVATURE	% GRADE UP DOWN	CORREC-TION	CORRECTION
2,005		LEVEL	0	0
1,000		1.5	30	-30
300		LEVEL	0	0
980		1.3	-26	26
3,020		LEVEL	0	0
30,375				
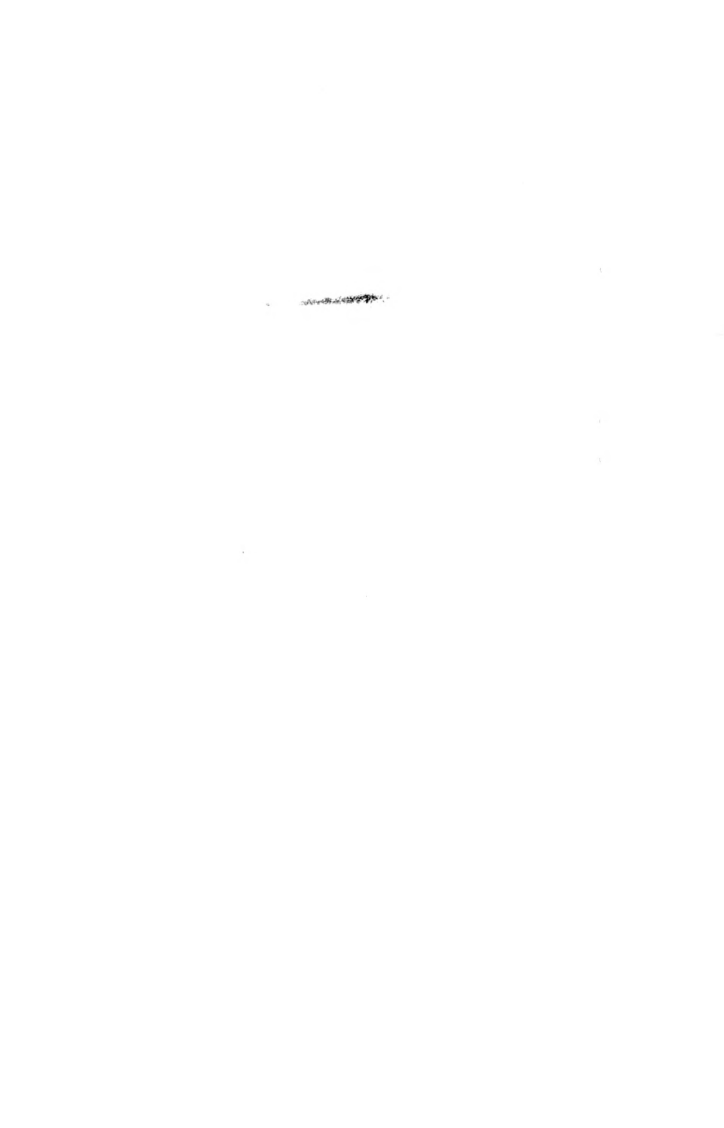
LENGTH	CURVATURE	% GRADE UP	DOWN	CORRECTION	CORRECTION
3,100		LEVEL		0	0
400			0.75	-15	15
1,600			0.94	-18.8	18.8
700			0.3	-6	6
175	2	0.69		15	-12.6
1,125		0.69		13.8	-13.8
1,000		LEVEL		0	0
3,000			0.4	-8	8
1,800			0.84	-16.8	16.8
200	2		0.84	-15.6	18
2,400			1.3	-26	26
3,900		LEVEL		0	0
225		1		20	-20
		SPOON RIVER			
375		1		20	-20
2,780		2		40	-40
700		1		20	-20
325		0.46		9.2	-9.2
300			1	-20	20
340		LEVEL		0	0
100		0.1		2	-2
680		0.74		14.8	-14.8
700		0.25		5	-5
200	3	0.25		6.8	-3.2
1,350			0.11	-2.2	2.2
27,475					

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| | | MAQUON - GILSON | | | GILSON - MAQUON |
LENGTH	CURVATURE	% GRADE UP	% GRADE DOWN	CORREC-TION	CORRECTION
2,075			0.11	- 2.2	2.2
200	3		0.11	- 0.4	4
1,500			0.11	- 2.2	2.2
2,300		0.83		16.6	-16.6
3,800		LEVEL		0	0
1,600		0.81		16.2	-16.2
900		0.78		15.6	-15.6
1,000		LEVEL		0	0
800			0.88	-17.6	17.6
1,000			1.5	-30	30
300		LEVEL		0	0
975			1.5	-30	30
530		LEVEL		0	0
1,370		1.5		30	-30
200	1	1.5		30.6	-24.9
1,630		1.5		30	-30
200		1.05		21	-21
990		0.42		8.4	- 8.4
955		0.16		3.2	- 3.2
200	3	0.16		5	- 1.4
550		0.16		3.2	- 3.2

23,075

LENGTH	CURVATURE	% GRADE UP	DOWN	CORRECTION	CORRECTION
255			0.16	-3.2	3.2
2,000			0.15	-3	3
145		1		20	-20
200	3	1		21.8	-18.2
655		1		20	-20
1,100			0.91	-18.2	18.2
800		LEVEL		0	0
595		2		40.	-40.
200	3	2		41.8	-38.2
55		2		40	-40
750		LEVEL		0	0
1,100		2.		-40	40
250		LEVEL		0	0
1,650		2		40	-40
600		1		20	-20
900		LEVEL		0	0
1,700		0.18		3.6	- 3.6
700		0.72		14.4	-14.4
2,950		1.1		22	-22
550		LEVEL		0	0
700			0.86	-15.2	15.2
400		LEVEL		0	0

| GILSON - KNOXVILLE | | | | KNOXVILLE - GILSON |
LENGTH	CURVATURE	% GRADE UP DOWN	CORREC-TION	CORRECTION
700		0.72	-14.4	14.4
900		1.8	-36	36
500		1.2	-24	24
500		1.7	-34	34
300		2.	-40	40
1,200		1.1	22	-22
480		LEVEL	0	0
200	3	DO	1.8	1.8
470		DO	0	0
800		2.	40	-40
300		0.7	14	-14
700		0.43	-8.6	8.6
500		0.2	4	- 4
480		0.3	6	- 6
600		0.83	16.6	-16.6
900		LEVEL	0	0
200	30	DO	18	18
19,985				

LENGTH	CURVATURE	% GRADE UP DOWN	CORRECTION	CORRECTION
725		LEVEL	0	0
200	30	DO	18	18
1,600		DO	0	0
175	3	DO	1.8	1.8
25	3	0.57	13.2	-9.6
675		0.57	11.4	-11.4
200		LEVEL	0	0
C. B. and Q. Main Line				
100		LEVEL	0	0
400		0.67 -13.4		13.4
550		LEVEL	0	0
350		0.47	9.4	-9.4
400		0.77 -15.4		15.4
660		2 -40		40
1,600		LEVEL	0	0
700		0.7 -14		14
800		LEVEL	0	0
500		1	20	-20
600		LEVEL	0	0
500		1 -20		20
600		LEVEL	0	0
1,120		1.5	30	-30
100	3	1.5	31.8	-28.2
100	3	1.4	29.8	-26.2
13,180				

E. GALESBURG - GALESBURG LIMITS				GALESBUTG LIM - E. GALESBURG
LENGTH	CURVATURE	% GRADE UP DOWN	CORREC- TION	CORRECTION
120		1.4	28	-28
900		0.33	-6.6	6.6
700		LEVEL	0	0
1,400		0.3	-6	6
100		0.17	-3.4	3.4
200	3	0.17	-1.6	5.2
300		0.17	-3.4	3.4
400		2	-40	40
1,000		LEVEL	0	0
800		1.5	30	-30
400		LEVEL	0	0
1,140		0.8	-16	16
C. B. and Q. SPUR				
1,120		LEVEL	0	0
1,300		0.6	12	-12
1,500		0.2	-4	4
11,380				

(B). EQUIPMENT

The car equipment will essentially
consist of the following apparatus:

(1) 4,G. E. 66-A-9 commutating pole motors of
125 hp. each with a gear ratio of pinion 29 to
gear 60 (= 2.07) Since the service involves
the use of both 600 and 1200 volts, the motors
are to be wound for 1200 volts. The motor cir-
cuits will remain the same, which will result
in operation at half speed on a 600-volt trolley.
The motors will be operated in series on 1200
volts and in multiple on 600 volts.

(2) Since single cars are to be aperated, the
Sprague - General Electric Type MK (hand operated)
control will be used.

(3) In order that the control and auxiliary
circuits may be operated at 600 volts, whether
the car is running on 600 or 1200 volts, a dyn-
amotor will be a part of the equipment. A switch
also will be supplied to connect the control cir-
cuits to the trolley on 600 volts, and to the
dynamotor on 1200 volts, so that the control
circuits will always be operated from the same
patential.

Heaters are to be fed directly from
the 1200-volt trolley since they will be wound
and insulated to suit this voltage.

The car can be lighted from the 1200-
volt trolley by using special lamps and sockets
to eliminate fire hazard; it will be best, how-
ever, to supply the lamps from the law side of
the dynamotor.

The speed-time curves showing the
individual runs between the limits of Peoria and
Galesburg will be found on Sheet #12 and #13;
those for the return run, i. e., between the
limits of Galesburg and Peoria are shown on
Sheets #14 and #15.

The distance between the limits of the
termini finally determined is 44.32 miles,--
which constitutes the interurban portion of
the line. The final speed-time curves show that
a mean time of 1 hour, 29 minutes or, say, 1½ hours
is required to traverse this distance. Allowing
20 minutes for the additional 5.06 miles in the
terminals, a total time of 1 hour, 50 minutes
will be required for the run,-- which results in
a schedule speed of 31.1 miles per hour.

This total time of run is 17 minutes
in excess of the best running time of the C. B.
& Q. However, considering the fact that the
terminal of the project in Galesburg is within
the central (business) part of the city while
that of the C. B. & Q. is a considerable dis-
tance away from it, and, considering also that
the interurban will traverse the busier streets
of both terminals thus allowing much convenience
to the traveling public, -- it will be fair to
say that the schedules will be approximately
equalized and a preference for the electric rail-
way very likely will be shown.

Simultaneously with the speed-time
curves the current, voltage and power curves
were drawn as shown on Sheets #12, 13, 14, and 15.
The latter curves will be discussed later.

2. FINAL DETERMINATIONS REGARDING SCHEDULE AND EQUIPMENT

a. Schedule

Since the project is a double-track
line it will not be necessary to study the final
schedule shown on Sheet #16 with regard to points
of meeting of cars. This schedule does not show

the stops or their duration within the city-
limits, as these cannot be difinite. The
slope of the lines is dependent upon speed,
the co-targent of the angle which they make
with the horizontal representing the schedule
speed of the car.

It will be noted that in this schedule,
in accordance with the preliminary one, the
first trains leave both terminals simultaneously
at 5:00 A. M.; the run from Galesburg to Peoria
is made in 1 hour and 48 minutes, while 1 hour
and 50 minutes is the time required for the return
run. The final schedule further snows that a
total of 26 single runs is made throughout the
day. The time-table on Sheet #17 was derived
from this schedule.

3. ENERGY CURVES. LOAD DIAGRAM

The current-time curves were plotted
in amperes per car. The values for power were
plotted in kilowatt-seconds. By the use of a
planimeter the areas under the power curves were
determined. The energy consumed was found to
be

$$E= \frac{\text{Area undercurve} \times 5280}{3600 \times 45 \text{ tons} \times \text{length of line}} \quad \text{watt-hours/ton mile}$$

For the run from Galesburg to Peoria,
the energy consumption is 61 watt-hours per ton
mile, which during the return run 63 watt-hours per

ton mile are consumed.

The energy consumption of one car from each terminal for a single day is next plotted with time in minutes as abscissae and kilowatts as ordinates. The kilowatt values are taken from the power curves plotted in connection with the speed-time curves. The curve resulting from summing up these values is the load curve for the station.

Allowing for the possibility of four cars starting simultaneously, also allowing for the power required for lighting and heating, it is found that 1400 K W. is the maximum demand on the station. A quantity as small as this would hardly justify the construction of a power station, since it could be purchased at a favorable rate from Peoria. No power house therefore, will be built. The transmission line is to be erected by the power company. The electrical considerations and the specifications will be found in Section 5.

4. REASONS FOR THE SELECTION OF 1200-VOLT DISTRIBUTION

At present there are in operation three general systems: the 600-volt direct current, the three phase alternating current with induction motors and the single phase alternating current with commutating motors. Recently, a potential of 1200 volts direct current has become a recognized standard on interurban lines because it is conveniently interchangeable in operation at the same speed on 600 and on 1200-volt lines.

The polyphase system was left out of consideration because of the inability of polyphase motors to be operated on direct current. The trolley potential both in Peoria and Galesburg being 600 volts direct current, the choice lies between single phase alternating current and 600 or 1200 volts direct current.

The economical limit for direct current distribution at ordinary voltages of 450 to 600 at the motors, is from 8 to 10 miles as a maximum on each side of the station. The 1200 volt D. C. system reduces the fixed charges

by reducing the number of substations necessary
and by a saving in copper in the distribution
system, since at a high voltage a smaller cur-
rent will flow in the wire. An increase in
efficiency of the high voltage substation is
secured by an improvement of the load factor.
Substation units are required to be capable
of starting at least two cars simultaneously
without axceeding the overload quarantees;
as the running current of a train is only
about one third of the starting current and
since there are considerable periods when
coasting and braking that the car is taking
no current and periods when there are no
cars on a section fed by a particular sub-
station, -- a low load factor will result.
With the adoption of the high voltage sys-
tem, however, the length of the line fed by a
substation is greatly increased and con-
sequently the individual substation is
working for a greater percentage of the
total time; therefore the substation load
factor and efficiency are improved.

Single-phase motors at present are inferior to the direct current motor in efficiency and rapid accelerating qualities for a given rating. They are also considerably heavier for a given output thus increasing the weight of car to be accelerated for a given traffic return. Another disadvantage of the single-phase system is its low uncontrollable power factor. The direct current system has no apparatus on the car or between the car and the converters to lower the power factor; in fact, the converters permit the power factor of the transmission line to be raised. A lower power factor means proportionately higher current for a given capacity with increased initial cost of equipment and increased losses.

Alternating current trolley circuits affect adjacent circuits of all kinds on account of static and inductive disturbances. The cost estimate would have to include $300 to $500 per mile of route for telephone and telegraph protective devices. On the other hand, conductive influence of direct current due to differences in potential in the return circuit does not create any disturbance in the telephone, and protection for the

telegraph is easily provided.

The fact that 1200 volts and in some cases higher direct current potentials are used on more than 1900 miles of electric railroads in this country, furnishes in itself convincing evidence of the success of this proposed system with respect to initial cost, reliability and low cost of maintenance. It is interesting to note that of a total of 28 roads now using high voltage direct current apparatus, seventeen were completely new roads, 6 were operated by steam, 3 were previously operated by single-phase alternating current and 3 by 600 volts direct current. In every one of the 5roads that previously were operated at either 600-v. direct current or single-phase, the change to the higher system was made without interruption of the regular services, which speaks highly for the flexibility of the system.

5. TRANSMISSION LINE

1 GENERAL

Standard construction with center poles will be used. These poles will be 40 ft. long (with a 130 ft span), to enable the placing of cross-arms for trolley construction.

The three-phase system of alternating
current transmission has been standardized almost
exclusively for railway work. This is due to the
fact that poly-phase apparatus is necessary for
substation units in large sizes and that three-phase
system requires but three-fourths the copper of the
single-phase installation. Other polyphase sys-
tems, although more economical in copper, are com-
plicated because of the greater number of wires. The
three-phase system, therefore, will be employed in
the present case. The frequency will be 25 cycles
per sec.

To get an approximate value of the pres-
sure which will be consistent with economy, the
formula given by Mr. A. Still was employed. The
pressure in kilovolts is equal to

$$5.5 \sqrt{\text{distance of transmission (m)} + \frac{\text{hp. transmitted}}{200}}$$

In the case of the project the horse-power trans-
mitted is $\frac{1400 \text{ KW}}{746} = 1877$ the distance is 31.52 m.
Therefore the pressure

$$E = 5.5 \sqrt{31.52 + \frac{1877}{200}} = 35.2 \text{ K. V.} = 35,200 \text{ volts.}$$

The closest standard voltage is 33,000,--
which will be adopted for the present case.

Only one circuit will be installed; therefore, to be better able to withstand abnormal stresses it will be made mechanically stronger than would be the case if two parallel circuits were employed, when one would act as a relay for the other if a break-down should occur.

After carefully considering the advantages and disadvantages of both copper and aluminum wire, the former was decided upon.

Kelvin's law was not used in determining the size of the wire because it would result in a wire too small to withstand the mechanical stresses and weather conditions. The size of wire from the station at Peoria, where power will be purchased, to the Eden substation will be No. 4/0 B. & S., and for the section between the substations at Eden and Maquon the size of the conductor will be No. 0 B. & S.

(b) SPANS

1 The standard length of span will be 130 ft. At Spoon River, due to the long span, poles specially tested for greater strength will be used.

2.   The clearance between rail and conductor will in no case be less than 20 ft.

3.   When crossing over telephone wires, the clearance will not be less than 10 ft.

4.   The distance between wires will be 36 inches, except at Spoon River it will be 45 inches on account of the long span.

5.   The poles will be set in the ground to a depth of 6 ft.

(c) METHOD OF ARRANGING WIRES

        The "wish-bone" arm arrangement will be employed. As seen from Sheet #19, the wires are placed at the vertices of an equilateral triangle, with two conductors in one vertical and the third wire at the third vertex. To provide greater protection against lightning, a ground wire will be strung along the top of the poles, --these being 8 inches in diameter at the top.

(d) INSULATORS

        The pin type insulator will be used. The length of the pin will be such that the distance between the smallest petticoat and the cross-arm is 4 inches, which is one inch greater than the flash-over distance from the edge of the inner petticoat to the pin.

3. ELECTRICAL CONSIDERATIONS

(a) EDEN - MAQUON

Length, miles	20.78
Power from Eden substation, kw.	700
Power factor, full-load current leading	90%
Frequency, cycles per second	25
Voltage in line at Maquon	33,000
Voltage from line to neutral ($\frac{33000}{\sqrt{3}}$)	19,100
Assumed loss	5%
Actual loss	1.5%
Size of wire, No 0 B.&S., inches	0.325
Resistance per mile, ohms	0.529
Distance between wires, inches	36
Inductance per mile, henries	0.001853
Capacity per mile, micro-farads	0.0163

The remaining calculations were
performed by the use of hyperbolic functions
which give much greater accuracy than the
method of "drops".

Attenuation Coefficient ⎯⎯⎯⎯⎯⎯= 0.00063 + j 0.00107

Current per wire at Maquon ⎯⎯⎯⎯= 13.6∠25°50'

Natural Impedance ohms ⎯⎯⎯⎯⎯⎯=485∠-30°35'

Natural Admittance ⎯⎯⎯⎯⎯⎯⎯= 1/485∠30°35'

Voltage at Eden ⎯⎯⎯⎯⎯⎯⎯= 19,200

Current at Eden ⎯⎯⎯⎯⎯⎯= 14.06

Regulation ⎯⎯⎯⎯⎯⎯⎯⎯= 0.524 %

Line Efficiency ⎯⎯⎯⎯⎯⎯= 95.9%

Charging Current ⎯⎯⎯⎯⎯⎯= 0.99 amp.

(b) PEORIA - EDEN

Length, miles ------- ------------ ------10.74

Power from station at Peoria to Eden, kw. 1400

Voltage at Eden ------------------------ ----19,200

Size of wire, No. 0000 B. & S., inches   0.46

Resistance per mile, ohms ------------ 0.264

Inductance per mile, henries --------- 0.00171

Capacity per mile, micro-farads--------0.0177

Attenuation Coefficient ------0.000386+j0.000945

Natural Impedance ----------------368 $\underline{/-22^{\circ}15'}$

Natural Admittance ------------ 1/368$\underline{/22^{\circ}15'}$

Generated Voltage ------------ 19,500

Generated Current ------------ 27.8

Regulation ----------------   1.56%

Line Efficiency -----------------   99%

Charging Current -----------------0.583

(c)   PEORIA - ALGON

Regulation ------------------------ 2.096%

Charging Current ---------------   1.573

Natural Frequency ---------------- 1475

The foregoing calculations, resulting
in a regulation of 2% for the entire distance,
show that the sizes of #0 and # 4/0 of wire for
the two sections are more than suitable for this
transmission line.

6. SUBSTATIONS

1. LOCATION

There will be two substations of equal
capacity; one will be located at Eden, 10.74 miles
from Peoria, and the other at Maquon, 31.52 miles
from Peoria.

2 EQUIPMENT

To provide for lightning, heating and
the possibility of four cars starting simultaneously
the substation capacity must be larger than would
be indicated by the load curve.. The converters
being built for at least a 25% overload, momentary
overloads will be easily taken care of.

a CONVERTERS

Two 500-kw 1200-volt 25-cycle rotary
converter units will be installed in each substa-
tion,- one to act as a relay in case of emergency.
Compounded converters will be used to automatically
compensate for the drop due to line, transformers

and converter impedance.

5 TRANSFORMERS

Three single-phase 185-kw. 33000-volt
air-blast transformers will be installed for
each converter. The primary windings will be
connected in "Y" with the neutral solidly groun-
ded. The service may then be maintained in
case of trouble on one phase of the transmission
line, the other two wires and ground serving as
the circuit.

c. REACTANCES

To enable the direct current voltage
to be altered by the field rheostat or automat-
ically by compounding, which calls for a correspon-
ding change (by compounding, which calls for a
corresponding change) of the alternating current
voltage, a three-phase reactance, coil is pro-
vided between the low tension windings of the
transformer and the converter. Under heavy load,
the series field of a compound converter tends to
produce leading currents, which tendency is prac-
tically balanced by the reactance, improving the
power factor of transformers, lines and generators
when loaded.

One 75- k. v. a. 25-cycle 60-volt air-blast
reactance will be used for each transformer set.

a. BLOWER

The following amount of air will be
supplied by the blower:

Transformers, each requiring 750 cu. ft./min, - -2250

Reactance - - - - - - - - - - - - - 320
                                      ————
                                      2570

For the two units 5140 cu. ft. of air per
minute will be required, - in case both units should
be in use. A 6000 cu. ft./min (pressure of 7/8 oz.
per sq. *in.*) blower will be used; it is to be driven
by a 3-hp. three-phase induction motor.

(e) SWITCHBOARD

The switchboard panels are as follows:

A. C. Main Panels
    (1) Incoming main panel

    (2) High tension converter panel

D. C. Main Panels.
    (3) D. C. Converter Panel
    (4) D. C. Feeder Panel.

In addition to the above there will be
several auxiliary panels not incorporated in the
main switchboard: A. C. starting panel, blower
motor panel, and control storage battery panel.
The latter will be used for 120-volt storage

batteries which are required for lighting and for
the operation of motor-driven oil switches in case
the latter should be finally decided upon.

Besides the electrical equipment, other
details of the substation may be considered.

(f) CRANE

A 25-ton crane will be installed not only
for its convenience but also on account of the
actual economy of building floor area, which is
possible with its use. The possible saving of
time when it becomes necessary to work on machinery
rapidly, need hardly be mentioned and the value
of a crane at such times is obvious.

(g) DRAINAGE

The walls of the air-blast chamber will
be water-proofed and the substation built at such
an elevation that water will not stand on the
floor of the air-blast chamber. This will be
done to prevent any possible damage to the trans-
formers by the warm air from the blower picking up
moisture and depositing it in transformers which
are not in service.

(h) BUILDING

The front and sectional elevations,

the plan and the wiring diagram will be found
on Sheets #20,21,22,and 23.

7 DISTRIBUTION SYSTEM

(a) FEEDERS

The size of feeder determined for
the section from the Eden substation, was
500,000 c. m. (without taper), giving an R I
drop of 193 volts; for the section from the
Maquon substation the size determined was
550,000. c. m. with an R I drop of 209 volts.

(b) TROLLEY

The trolley wire will be No. 000 in
size and will be attached to the hanger by
clips embracing only the upper half of the wire.
The trolley wire will be tapped on the feeder
at intervals of 1000 ft.

The feeders and trolley wire will be
carried on the same poles as the transmission
line. Lightning arresters are to be installed
every 1000 ft. and will be tapped alternately
to the trolley and the feeder. Double bracket
construction is to be used; it is shown on Sheet
#19.

8 CONCLUSION

Since the project traverses a territory

considered one of the most favorable in Illinois,
since its terminals are two important and rapidly
growing cities, and since similar lines will soon
be built between Peoria and the cities of Keokuk
and Quincy, it is obvious taking into consideration
the conclusions of part A, that the success of the
project is assured.

BIBLIOGRAPHY

Standard Handbook

Foster: "Elec. Engineers' Pocketbook"

Gotshall: "Elec. Railway Economies"

Harding: "Electric Railway Engineering"

Hobart: "Electric Trains"

Ashe: "Electric Railways."

Sheldon)
  and   ): "Electric Traction and Transmission."
Hausmann)
Still: "Overhead Electric Power Transmission."

Lundquist: "Transmission line Construction."

Gillette: "Cost Data."

Nichols: "Lecture notes and Cost Data."

Elec. ry. jour. Aug. 23 - 1913

                 Sept. 6 - 1913

                 Sept.20 - 1913

                 Nov. 15 - 1913

Trans. A. I. E. E. 1902 pg. 901
                               169
                               129
                               210
                               809
                    1903 pg. 91
                               133
                               657
                    1904 pg. 691
                    1905 pg.1097
                    1910 pg. 1
                              1461
                              1495
General Elec. Rev. Oct. 1913

                    Nov. 1913

<u>List of Drawings</u>

OVERHEAD CONSTRUCTION... CENTER POLES.
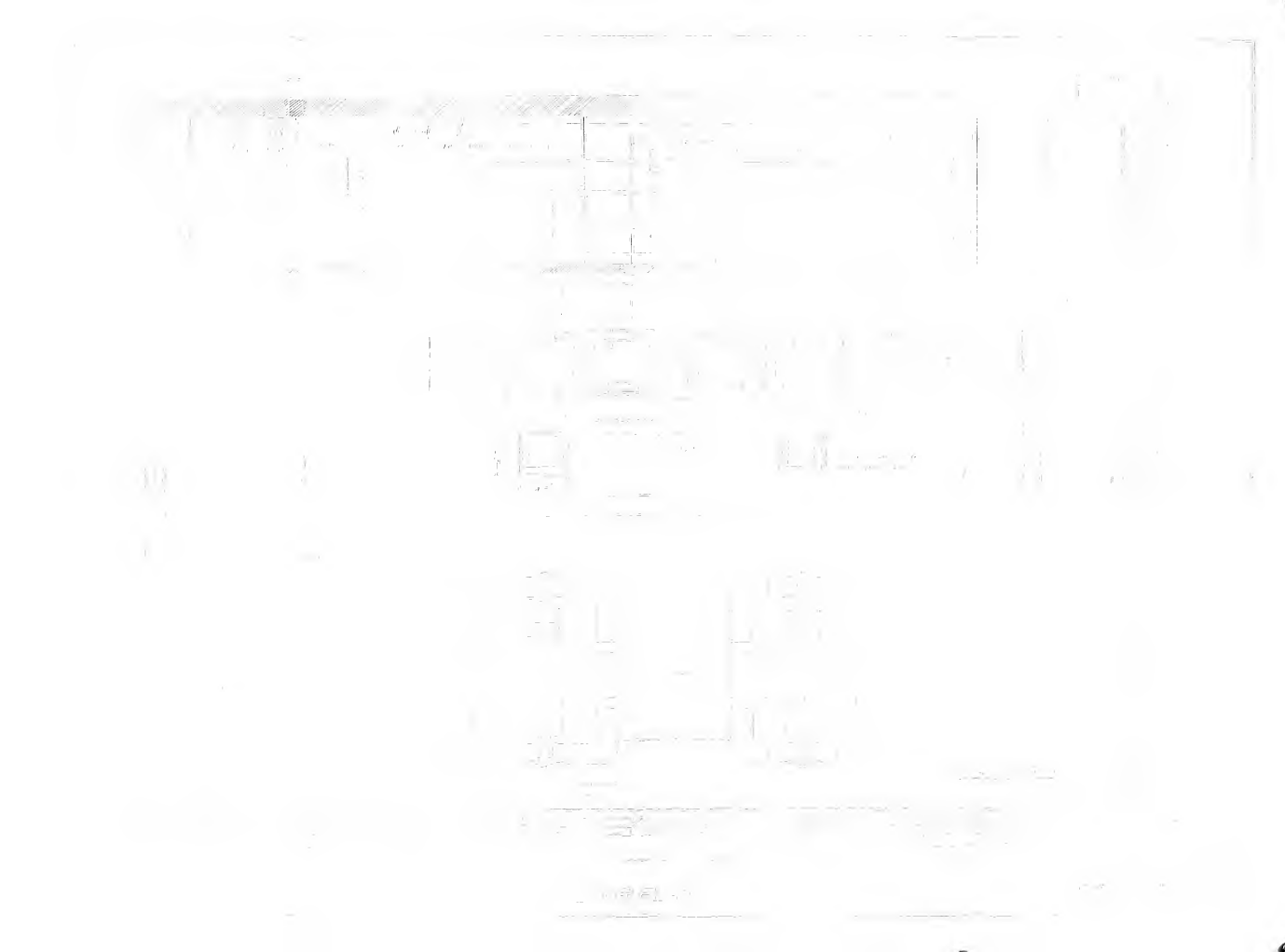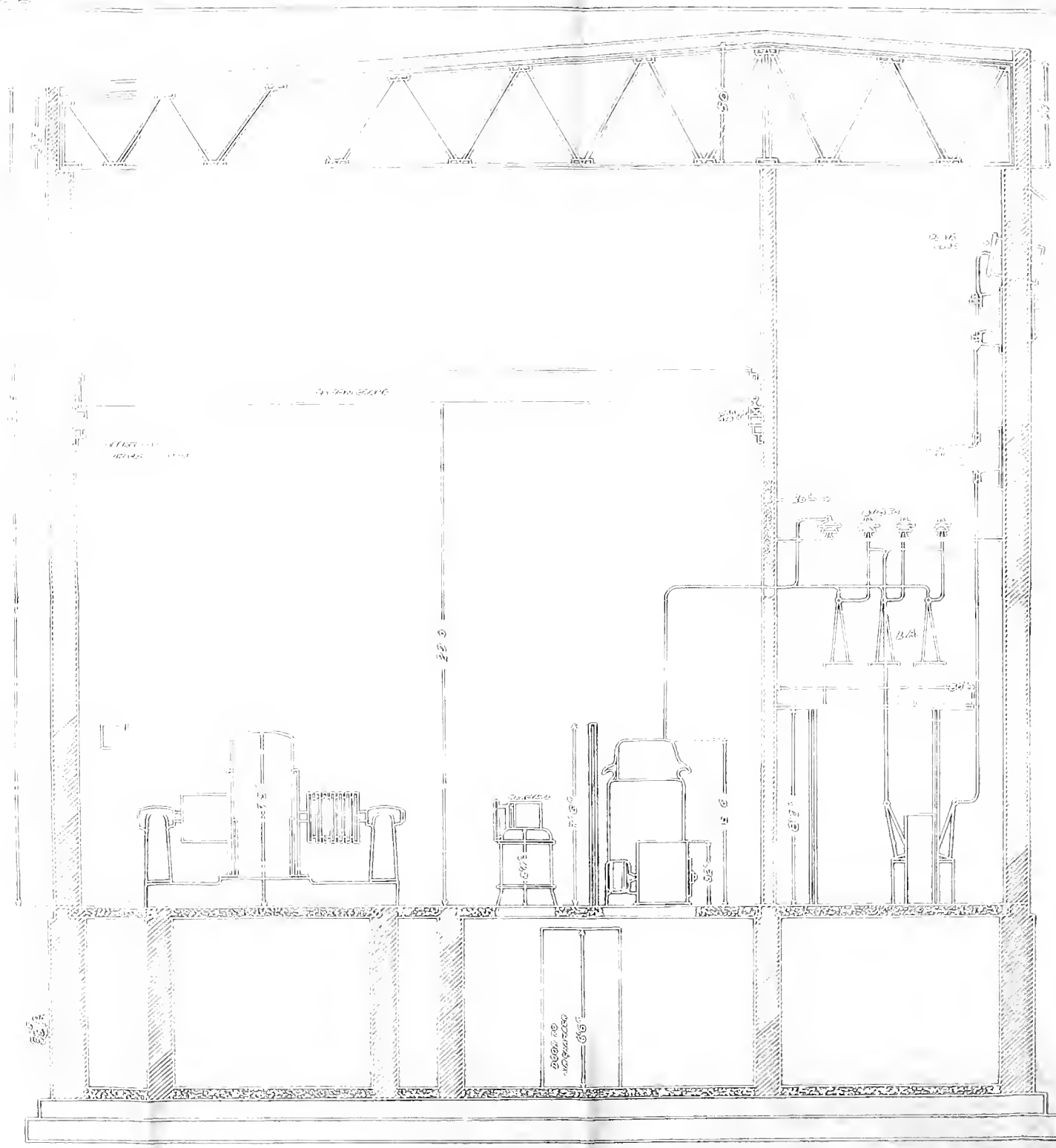
SECTIONAL ELEVATION

SUBSTATION
PEORIA GALESBURG ELECTRIC RY
5-18-14   SCALE 3/8"=1'

WIRING DIAGRAM

SUBSTATION